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A CASE STUDY

Advance applications of bioremediation and its impact on human and environmental health

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Bioremediation is an effective innovative technology, in the field of biotechnology for the treatment of a wide variety of contaminants. It is a tool box for wider application in the area of environmental protection. Bioremediation, provides an opportunity to solve the problem in the field of solid waste by detoxifying effluents /hazardous wastes. Due to its comparatively low cost and environmental impact, it offers attractive and more conventional clean-up technologies. Large amounts of toxic waste have been dispersed in thousands of contaminated sites spread across our nation. Thus, every one of us exposed the contamination from past and present industrial practices, emissions in natural resources (air, water and soil) even in the most remote regions. The toxic waste is creating the risk for human and environmental health and there are evidence that this cocktail of pollutants create a major contribution to the global epidemic of cancer and other degenerative diseases. Now the challenge is to develop innovative and cost-effective solutions to decontaminate polluted environments.

Key words : Bioremediation, Biological intervention, Noxious effects, Bio-stimulation, Phytoremediation, Rhizoremediation

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INTRODUCTION

As we know that the industrialization is increasing day by day and extractions of natural resources have resulted in large scale environmental contamination and pollution (King *et al.*, 1997 and Sei *et al.*, 2001). Huge amounts of toxic waste have been dispersed in millions of contaminated sites spread across our nation (Flathman *et al.*, 1993 and Prescott *et al.*, 2002). The risk for the human and environmental health is rising day by day and there is evidence that this combination of pollutants is a huge contributor to the global epidemic of cancer and other lethal diseases shown in Fig. 1 (Umrania, 2006; Hinchee *et al.*, 1995 and Arsam *et al.*, 2007).

Bioremediation is the use of biological interventions of biodiversity for mitigation (and wherever possible complete elimination) of the noxious effects caused by environmental pollutants in a given site (Ma *et al.*, 2007 and Gadd, 1992). It works on the principles of

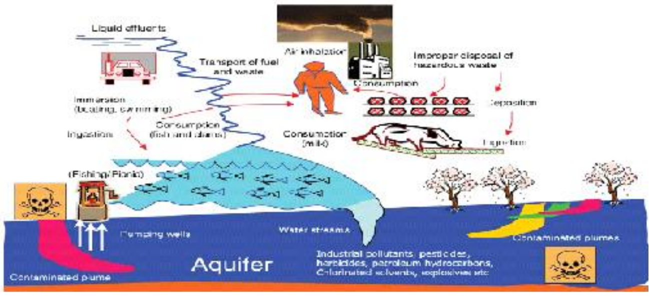
Liquid effluents
Transport of fuel and waste
Air inhalation
Improper disposal of hazardous waste
Consumption
Immersion (boating, swimming)
Deposition
Consumption (fish and clams)
Ingestion
Consumption (milk)
Ingestion
(Fishing/Picnic)
Pumping wells
Water streams
Contaminated plumes
Aquifer
Industrial pollutants, pesticides, herbicides, petroleum hydrocarbons, Chlorinated solvents, explosives etc
Contaminated plume

Fig.1: Transport of inorganic or organic contaminants/ pollutants and their harmful effects

biogeochemical cycling shown in Fig. 2 and 3. If the process occurs in the same place then it is called *in-situ* bioremediation. There are two types of pollutants are remediate by this technology *i.e.* inorganic and organic pollutants. In contrast, deliberate relocation of the contaminated material (soil and water) to a different place to accelerate biocatalysis is referred to as *ex-situ* bioremediation (Dua *et al.*, 2002). Bioremediation has been successfully applied for clean up of soil, surface water, groundwater, sediments and ecosystem restoration. It has been clearly demonstrated that a number of xenobiotics including nitro-glycerine (explosive) can be cleaned up through bioremediation (Olson *et al.*, 2001). Bioremediation is generally considered to include natural attenuation (little or no human action), bio-stimulation or bio-augmentation, the deliberate addition of natural or engineered micro-organisms to accelerate the desired catalytic capabilities (Thomas and Wood, 2008; Bouwer and Zehnder, 1993 and Muhammad *et al.*, 2007). Thus, bioremediation, phytoremediation and rhizoremediation contribute significantly to the fate of hazardous waste and can be used to remove these unwanted compounds from the biosphere (Ma *et al.*, 2011 and Schroeder and Schwitzguebel, 2004).

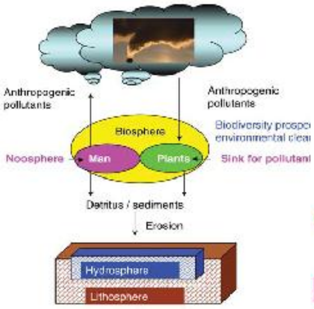

Fig.2:Biogeochemical cycle

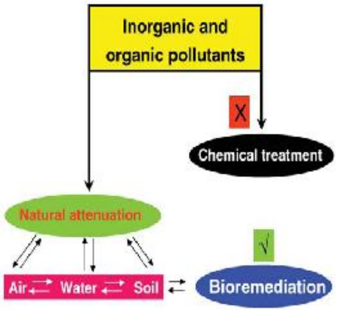

Fig.3: Natural attenuation and bioremediation

Different contaminants and their harmful effect :

There are several inorganic and organic pollutants which contaminate land and water bodies include heavy metals, metalloids, fluoride, cyanide, phenol, pesticides (DDT) and benzene etc (Strong and Burgess, 2008 and Prescott *et al.*, 2002). some of these are described here:

Arsenic :

Arsenic (As) is one of the most toxic elements present in soils and water. Arsenic contamination affects biological activities as a teratogen, carcinogen and mutagen as well as having detrimental effects on the immune system (Fig. 4 and 5).

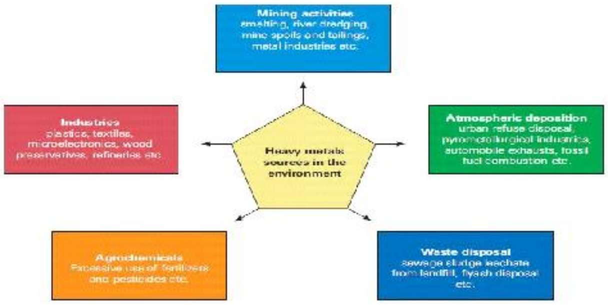
Mining activities
smelting, river dredging, mine spoils and tailings, metal industries etc.
Industries
plastics, textiles, microelectronics, wood preservatives, refineries etc
Heavy metals sources in the environment
Atmospheric deposition
urban refuse disposal, pyrometallurgical industries, automobile exhausts, fossil fuel combustion etc.
Agrochemicals
Excessive use of fertilizers and pesticides etc.
Waste disposal
sewage sludge leachate from landfill, flyash disposal etc.

Fig.4: Source of heavy metals in the environment

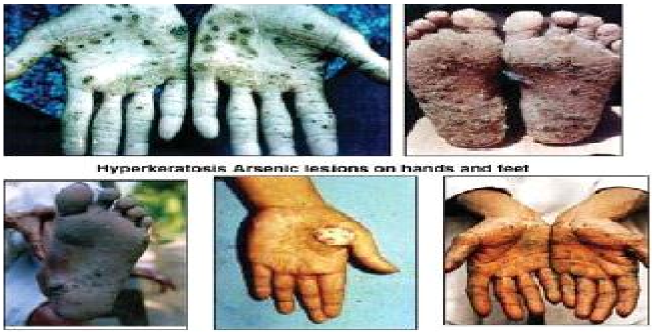

Fig.5: Arsenic toxicity

Fluoride :

Excess fluoride in drinking water causes harmful effects such as dental fluorosis and skeletal fluorosis (Fig. 6 and 7).

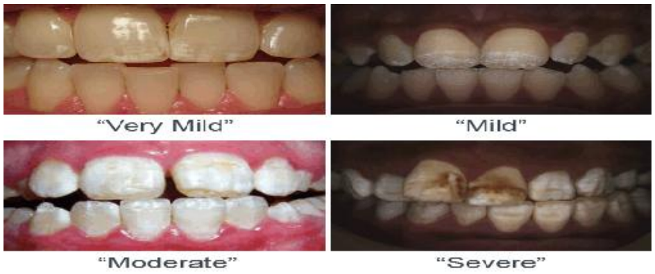

Fig. 6: Dental fluorosis

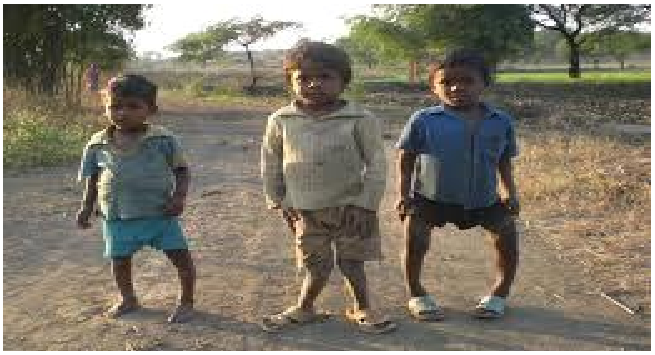

Fig. 7: Skeletal fluorosis

Why do we need bioremediation?

- Natural attenuation (little or no need to human action)
- Eco friendly technology.
- Conventional method to remove, reduce or mitigate toxic substance introduced into soil or ground water via human activities
- This technology is cost effective and not generates secondary pollution.
- The challenges are to develop innovative and cost-effective solutions to decontaminate polluted environments, to make them safe for human habitation and consumption, and to protect the functioning of the ecosystems (Prescott *et al.*, 2002 and Kao *et al.*, 2006).

Mechanism involved in bioremediation :

The role of bioremediation for cleanup of organics and inorganic including various uses are described in following (Fig. 8 and 9). These mechanisms are dealt in an orderly fashion as the sequence of how contaminants come into contact with the plant system, rhizosphere and transportation processes (Baldwin *et al.*, 2008 and Tang *et al.*, 2007). These mechanisms are interrelated and dependent upon plant physiological processes driven by solar energy, rhizospheric processes and other available precursors (Lokhande and Patill, 2009; Prescott *et al.*, 2002 and Giller *et al.*, 1998). Therefore, in bioremediation application, multiple mechanisms are involved depending on the designed application these are:

- Phytoremediation
- Biostimulation
- Landbased treatment
- Bioaugmentation
- Bioventing
- Biosparging
- Genetic engineering.

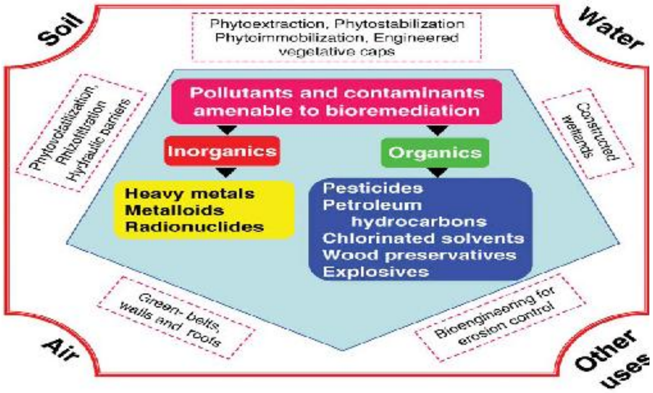

Fig. 8: Multiple mechanisms that are involved in bioremediation of soil, water, air and other miscellaneous uses

Removal mechanism of pesticides :

Research in examining the fate and degradation of pesticides in agricultural soils started over 50 years ago. Wide range of catabolic reactions is mediated by bacterial enzymes. The capacity of bacteria and fungi to degrade xenobiotics is impressive (Natrajan, 2008 and Blanca *et*

Fig. 9: Green walls for cleanup of pariculate and gaseous contaminants from air and also to enhance aesthetics

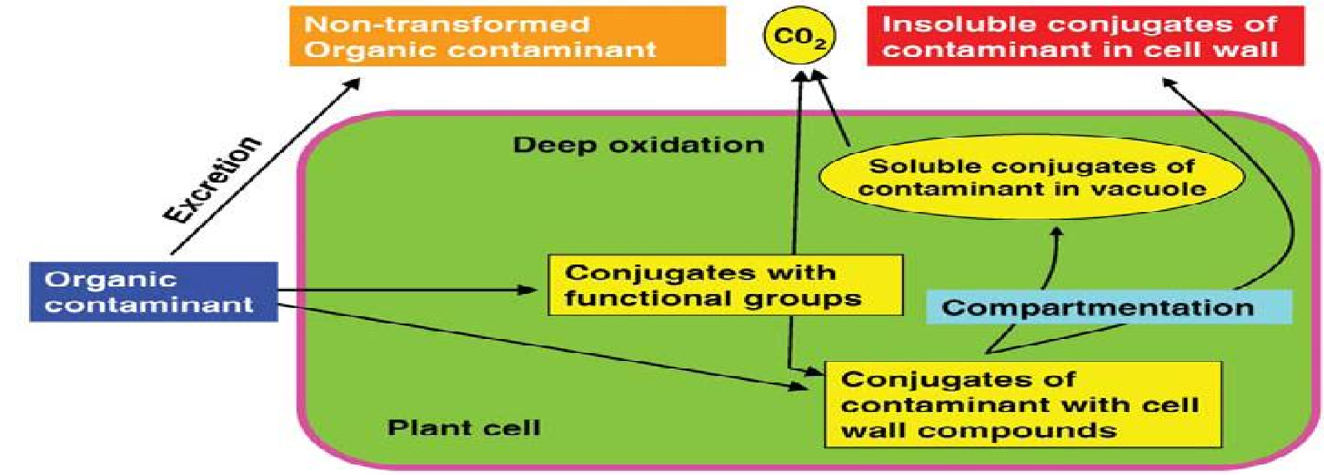
Non-transformed Organic contaminant
CO_2
Insoluble conjugates of contaminant in cell wall
Excretion
Deep oxidation
Soluble conjugates of contaminant in vacuole
Organic contaminant
Conjugates with functional groups
Compartmentation
Conjugates of contaminant with cell wall compounds
Plant cell

Fig. 10: Detoxification of xenobiotics

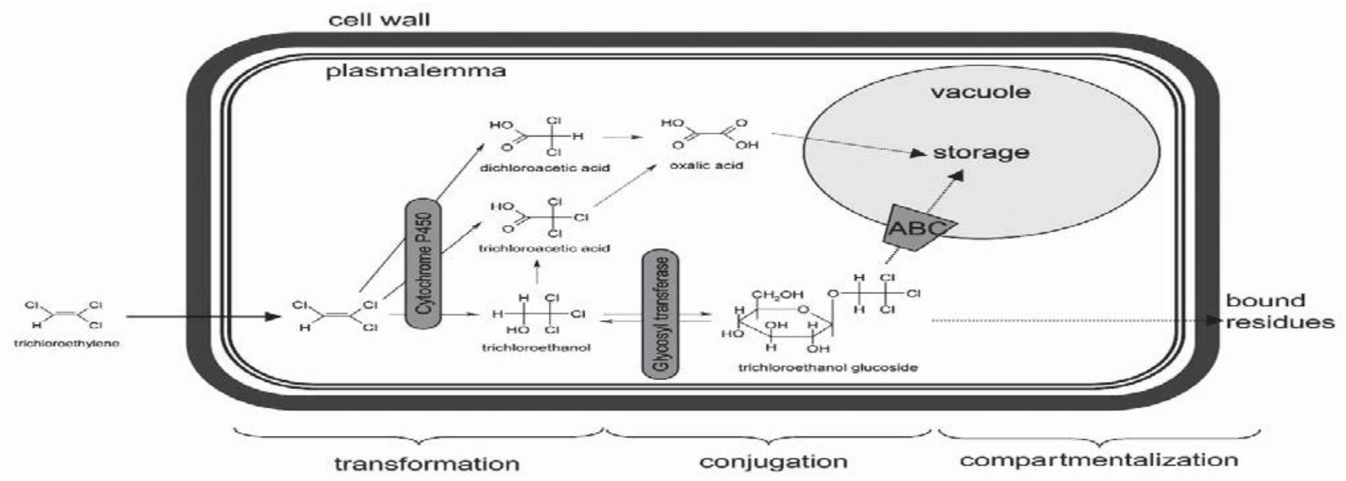

Fig. 11: The pathway representing the metabolism of trichloroethylene (TCE) in plant tissues. Phase I, activation / transformation of TCE to trichloroethanol; phase II, conjugation with a plant molecule; phase III, sequestration of the conjugate into the cell wall or within the vacuole (Source: Reichenauer and Germida 2008 and Van Aken 2009)

al., 2008). Fig. 10 and 11 shows the detoxification of xenobiotics.

Conclusion :

In application of bioremediation in environmental technologies both organic and inorganic contaminants can be removed through different processes (physico-chemical and biological) in which biosurfactants are involved. Due to their biodegradability and low toxicity, they are very promising for use in environmental biotechnologies. The commercial success of biosurfactants is still limited by their high production cost. Optimized growth conditions using cheap renewable substrates (agro-industrial wastes) and novel, efficient methods for isolation and purification of biosurfactants could make their production more economically feasible. Rapid industrialization and technology development have adverse side effects like soil contamination and degrading soil health. Due to the complexity involved in the conventional methods for remediation of soil, the use of microbes has arisen as a time-saver for bioremediation.

However, bioremediation technology has limitations; several micro-organisms cannot break toxic metals into harmless metabolites, and these have inhibitory effects on microbial activity. Modification in the outer membrane proteins of bacteria with potential bioremediation properties for improving metal binding abilities is the likely way to enhance their capacity for biotransformation of toxic metals. Future studies should focus on the factors involved in improving *in situ* bioremediation strategies using genetically engineered micro-organisms (GEM) and also the applicability and adaptability of these GEMs in all the possible adverse/stress conditions and multiple-heavy-metal-polluted conditions. The reluctance among the public to accept GEM for bioremediation also needs to be considered in future studies, and they must proved non-toxic to the environment. Another important aspect regarding biological remediation technologies is the use of biosurfactant in the process on a large scale. To felicitate this process, new techniques should be developed such as foams or micro-foams (colloidal gas aphrons-CGA) in conjunction with biosurfactants. Bioremediation is cost effective, solar driven, faster than natural attenuation, high public acceptance including enhancement of aesthetics, and generates less secondary wastes with fewer air and water emissions. Bioremediation has emerged as an integrated ‘toolbox’ for environmental cleanup and ecosystem service provider.

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